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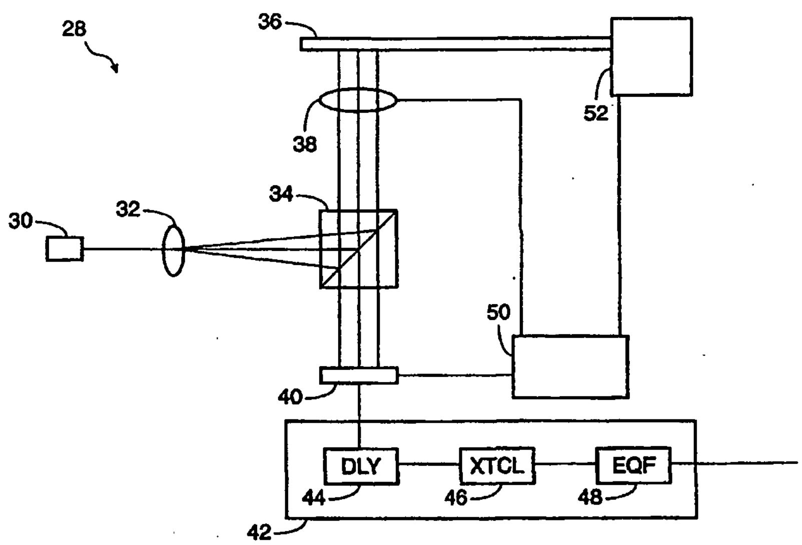

(57) Abstract

A multidimensional optical recording medium and recording and playback apparatus of the same are disclosed. The multidimensional optical recording medium includes a plurality of tracks having a tangential length, a radial width, and a track center. Each of the plurality of tracks is formed at a predetermined interval for writing data therein. At least one mark as encoded data is formed in at least one of the plurality of tracks. The data is encoded by modulating at least one of tangential position, tangential length, radial width, radial offset, or mark characteristic such as depth or reflectivity. The recording and playback apparatus include at least one light source for radiating at least one light beam to the optical recording medium. The light beam is arranged such that the light beam spot is able to write and/or read marks anywhere within a track.

SPECIFICATION

TITLE OF THE INVENTION

MULTIDIMENSIONAL OPTICAL RECORDING MEDIUM AND RECORDING AND PLAYBACK APPARATUS OF THE SAME

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates in general to the field of recording media and recording and playback apparatus of the same and more specifically to multidimensional optical recording media and recording and playback apparatus of the same.

2. The Conventional Art

Since their introduction, optical disc products have grown to represent a significant part of the total data storage and retrieval industry. This growth began with the Compact Audio Disc (CD-Audio) which has been one of the most successful products in consumer history. This growth continued with the Compact Read Only Memory Disc (CD-ROM) which has become the method of choice for the electronic distribution of information. This growth promises to continue with the introduction of the Digital Versatile Disc (DVD).

In general, in the conventional apparatus for playback of an optical disc, a light beam emitted by a laser optical source arranged either above or below the optical disc as an optical recording medium is focused as incident light by a beam splitter, an objective lens, and the like, and irradiates a track of the optical disc. Light reflected by the optical disc is directed to the beam splitter to be separated from the incident light, and supplied to a photodetector such as a photodiode. An optical signal from the beam splitter is converted by the photodetector into an electrical signal and amplified. Then, data written on the track of the optical disc is read out as recorded data through a sample and hold circuit, a digitizer, a decoder, and the like.

In the conventional optical disc media for such an apparatus, data to be played back from a track of the optical disc is usually arranged along the track direction in a one-dimensional manner. The data is represented by a series of pits or marks that are formed at desired intervals along the tangential length of the track. Taken together, the marks represent a bit stream with the absence of a mark being a logical 0 and the presence of a mark being a logical 1. Since this encoding scheme or alphabet only contains two symbols, it is called a binary encoding scheme.

One of the fundamental parameters involved in the measurement of performance in data storage devices is how much data the media can hold per unit area. This is known as density. There exists a constant drive in the industry to increase the density of the media.

One conventional approach to increasing the density of optical disc products has been to employ shorter wavelength laser optical sources and higher numerical aperture (NA) optics. This allows the optical disc to utilize smaller marks which can be placed closer together in the tangential direction and further allows the optical disc to utilize narrower tracks which can be placed closer together in the radial direction. For example, DVD obtains an improvement in density over earlier CD technologies by employing a 635 nm laser optical source and 0.6 NA optics, as opposed to the 820 nm laser optical source and 0.45 NA employed by earlier CD technologies. Among the drawbacks to such an approach however is the fact that each improvement in density requires major investments in all aspects of the optical disc industry, including lasers, optics, materials, and electronics. It also means that every step forward results in a significant departure from the existing technology and manufacturing base.

Another approach that has been proposed for increasing the density of optical disc products has been to employ guide tracks on either side of each data track and to vary the placement of the marks in the track width or radial direction along the track length between these guide tracks. This allows the optical disc to utilize the value of the radial distance from the guide track as an additional data encoding variable beyond the simple binary system of earlier CD technologies. Among the drawbacks to such an approach however is the fact that the use of guide tracks is extremely costly in terms of the disc surface area that is squandered that can be better used to store additional data, thereby increasing the overall density of the media. Further, the use of guide tracks represents a significant departure from the existing technology and disc format, thereby making a backwards compatible apparatus, one that will operate with new as well as existing media, substantially more difficult to manufacture.

OBJECTS AND ADVANTAGES OF THE INVENTION

Accordingly, it is an object of the present invention to provide a high density optical disc recording medium and recording and playback apparatus of the same without requiring a major investment in all aspects of the optical disc industry.

It is a further object of the present invention to provide a high density optical disc recording medium and recording and playback apparatus of the same without wasting real estate.

Yet a further object of the present invention is to provide a high density optical disc recording medium and recording and playback apparatus of the same without significantly departing from the existing technology and thereby making such apparatus manufacturable with the existing manufacturing base.

These and many other objects and advantages of the present invention will become apparent to those of ordinary skill in the art from a consideration of the drawings and ensuing description of the invention.

SUMMARY OF THE INVENTION

A multidimensional optical recording medium and recording and playback apparatus of the same are disclosed. The multidimensional optical recording medium includes a plurality of tracks having a tangential length, a radial width, and a track center. Each of the plurality of tracks is formed at a predetermined interval for writing data therein. At least one mark as encoded data is formed in at least one of the plurality of tracks. The data is encoded by modulating at least one of tangential position, tangential length, radial width, radial offset, or mark characteristic such as depth or reflectivity. The recording and playback apparatus include at least one light source for radiating at least one light beam to the optical recording medium. The light beam is arranged such that the light beam spot is able to write and/or read marks anywhere within a track.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a schematic of a track of a multidimensional optical recording medium according to the present invention.

FIG. 2 is a block diagram of a playback apparatus for the multidimensional optical recording medium according to the present invention.

FIG. 3 is a schematic of three light spots on a track of the multidimensional optical recording medium according to the present invention.

FIG. 4 is a block diagram of a radial offset decoder for the playback apparatus for the multidimensional optical recording medium according to the present invention.

FIG. 5 is a block diagram of a radial width decoder for the playback apparatus for the multidimensional optical recording medium according to the present invention.

FIG. 6 is a block diagram of a recording apparatus for the multidimensional optical recording medium according to the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Those of ordinary skill in the art will realize that the following description of the present invention is illustrative only and is not intended to be in any way limiting. Other embodiments of the invention will readily suggest themselves to such skilled persons from an examination of the within disclosure.

Recall that in a conventional optical disc medium, data to be played back from a track of the optical disc is usually arranged along the track direction in a one-dimensional manner. In addition, each mark of course has a mark width and each track of course has a track width. In one-dimensional recording, the mark width is used to provide a signal for playback and the track width is used only for track separation. The track separation is great enough however that at least a portion of the track width can also be used for multidimensional recording as disclosed below.

Turning to FIG. 1, a schematic of track 10 of a multidimensional recording medium according to the present invention is shown. Track 10 is shown to have track center 12. For reference purposes, track center 12 is shown as a line in the schematic. In the preferred embodiment of the multidimensional recording medium however, no such line would appear. Track center 12 can be established in a number of ways. First, track center 12 can be established by reference to a series of servo marks 14, 16 which occur at specified distances along track 10. Alternatively, track center 12 can be established by reference to track center data marks (not shown) which occur at specified data points within the data stream encoded into track 10. For example, a track center data mark can be encoded into the data stream after a predetermined number of nibbles, bytes, words, etc. of data.

On and along either side of track center 12 shown in FIG. 1 are various marks representing encoded data. Mark 18 is shown on track center 12 and has the same length X18, measured along track center 12, and width Y18, measured perpendicular to track center 12. Mark 20 is shown above or to the left of track center 12 and has length X20, which is longer than X18, and a width Y20, which is the same as Y18. The amount of offset of mark 20 from track center 12 is designated as R20 and is the distance from the centerline of mark 20 to track center 12. Those of ordinary skill in the art will recognize that reference points other than the centerline of the mark could be used to define the offset and these should be considered within the scope of the disclosed invention. Mark 22 is shown below or to the

right of track center 12 and has a length X22 and a width Y22, each of which is greater than X18 and Y18 respectively. The amount of offset of mark 22 (R22) is greater in absolute terms than the offset for mark 20 (R20). In order to distinguish the direction of the offsets, offsets above or to the left of track center 12 (R20) are given negative signs and offsets below or to the right of track center 12 (R22) are given positive signs. Mark 24 is shown above or to the left of track center 12 and has length X24, which is longer than X18, and a width Y24, which is narrower than Y18. The amount of offset of mark 24 (R24) is greater in absolute terms than the offset for mark 20 (R20) but both would have a negative sign. Mark 26 is shown below or to the right of track center 12 and has length X26, which is shorter than X18, and a width Y26, which is wider than Y18. The amount of offset of mark 26 (R26) is lesser in absolute terms than the offset for mark 22 (R22) but both would have a positive sign. Taken together, marks 18, 20, 22, 24, and 26 demonstrate various combinations of length, width, and offset. However, those of ordinary skill in the art will recognize that other combinations are possible and these should be considered within the scope of the disclosed invention.

In an optical disc application, track 10 follows a substantially circular path. The radius of the circular path is measured from the center of the optical disc. With respect to FIG. 1, the center of the optical disc (not shown) would be below or to the right of track center 12 and the direction of rotation of the optical disc would be to the left. In this reference scheme, mark 20, for example, has tangential length X20, radial width Y20, and radial offset R20.

Recall that in conventional optical disc media, data to be played back from a track of the optical disc is encoded in binary. If the number of symbols in the encoding alphabet is M, M being 2 for binary, for example, the gain in density to binary encoding is roughly $K = \log_2 M$. Based on this, estimates of the density gains represented by the addition of radial offset and/or radial width to conventional binary encoding can be made. Assume for these estimates that Dm is the minimum width of the mark, Dt is the maximum width of the track, ε is the minimum measurable difference in radial width, and δ is the minimum measurable difference in the radial offset. Dm, Dt, ε, and δ will depend on the capabilities of the hardware used. The gain in density represented by the addition of radial offset is $K1 = \log_2 [(Dt\text{-}Dm)/\delta]$. The gain in density represented by the addition of radial width is $K2 = \log_2 [(Dt\text{-}Dm)/\varepsilon]$. The gain in density represented by the addition of both radial offset and radial width is $K3 = \log_2 [\Psi(Dt\text{-}Dm)/\delta + \Psi(Dt\text{-}Dm\text{-}\varepsilon)/\delta + \Psi(Dt\text{-}Dm\text{-}2\,\varepsilon)/\delta + \ldots]$, where ΨX represents the largest integer less than or equal to X. For example, if the maximum track width Dt is 1.6 µm, the

minimum mark width Dm is 0.7 μm, the minimum measurable difference in the radial width ε is 0.025 μm, and the minimum measurable difference in the radial offset δ is 0.02 μm, then for radial offset, M1 is 45 which represents a five times gain in density. Likewise, for radial width, M2 is 36 which also represents a five times gain in density. Further, for radial offset and radial width in combination, M3 is 819 which represents a nine times gain in density. Taken individually or in combination, these gains in density represent a significant improvement over conventional optical disc media.

Those of ordinary skill in the art will recognize that the various marks of track 10 are similar to marks that are generally used. Accordingly, the present invention provides a high density optical disc recording medium which can be commercialized without requiring major investment in all aspects of the optical disc industry. Further, the present invention provides a high density optical disc recording medium without wasting disc surface area through the use of guide tracks. Further still, the present invention provides a high density optical disc recording medium without significantly departing from the existing technology and thereby can be manufactured with the existing manufacturing base.

Turning now to FIG. 2, a block diagram of a playback apparatus 28 for the multidimensional optical recording medium according to the present invention is shown. A single light beam emitted by laser diode 30 is directed as incident light to diffraction grating 32 where the light beam is split into a plurality of light beams. The plurality of light beams are directed to polarization beam splitter (PBS) and quarter wave plate (QWP) assembly 34 where the plurality of light beams are focussed onto optical disc 36 through objective lens 38. The focussed light beams form a plurality of light spots on the surface of optical disc 36. The plurality of light spots will be discussed further with respect to FIG. 3 below. Those of ordinary skill in the art will recognize that rather than single laser diode 30 and diffraction grating 32, a plurality of laser diodes could be used to generate the plurality of light beams.

Light reflected by optical disc 36 is directed to PBS and QWP assembly 34 through objective lens 38. The reflected light is separated from the incident light by PBS and QWP assembly 34 and is sent to photodetector array (PD) 40. PD 40 converts the reflected light into PD electrical signals which are transmitted to processor 42. The PD electrical signals can be described by the function PD(i) where PD(i) is the electrical signal from the ith photodetector associated with the ith light beam.

The PD electrical signals are transformed by processor 42 into processed (PDP) electrical signals that can be described by the function PDP(i). First, the PD electrical signals are transmitted to delay circuit (DLY) 44 where timing delays are introduced to compensate for the delays caused by the separation of the plurality of light spots in the tangential direction. Next, the DLY electrical signals are transmitted to cross talk canceler (XTCL) 46 which reduces the cross talk caused by reading marks in adjacent radial positions. For example, through thresholding, XTCL 46 can be implemented as

$$\begin{aligned} PDXT(i) &= PD(i) \quad && \text{if } PD(i) > PDSR \\ &= 0 && \text{otherwise} \end{aligned} \qquad (1)$$

where PDSR is the signal at PD(i) when the mark is separated from the ith light spot by the radial spot separation SR (see FIG. 3). Such a thresholding insures that the information about positions of the marks are present only in the photodetectors connected to the two spots radially nearest to the marks. Next, the XTCL electrical signals are transmitted to equalization filter (EQF) 48 which reduces intersymbol interference in the tangential direction. For example, through a tapped delay line filter, EQF 48 can be implemented as

$$PDP(i)(t) = PDXT(i)(t) - Kt[PDXT(i)(t-\tau) + PDXT(i)(t+\tau)] \qquad (2)$$

where Kt and τ are constants determined by intersymbol interference in the tangential direction. Finally, the PDP electrical signals are complete. The PDP electrical signals may be processed even further as will be discussed with respect to FIGs. 4 and 5 below.

Also shown in FIG. 2 are timing and servo control 50 and spindle motor 52. Timing and servo control 50 regulates the rotation speed and direction of spindle motor 52, positions objective lens 38 to be in focus and on track on optical disc 36, and provides timing information for data decoding. Spindle motor 52 rotates optical disc 36 at the desired speed and in the desired direction.

Those of ordinary skill in the art will recognize that the various components of playback apparatus 28 are similar to components that are generally available. Accordingly, the present invention provides a high density optical disc recording medium playback apparatus without significantly departing from existing technology. Further, the present invention provides a high density optical disc recording medium playback apparatus without wasting disc surface area through the use of guide tracks. Further still, the present invention provides a high density optical disc recording medium playback apparatus which can be manufactured with the existing manufacturing base without requiring a major investment in all aspects of the optical disc industry.

Turning now to FIG. 3, a schematic of three light spots 54, 56, 58 on track 10 of the multidimensional optical recording medium according to the present invention is shown. Light spot 56 is shown on track center 12. Light spot 54 is shown below or to the right of track center 12 by a distance SR and is shown behind light spot 56 by a distance ST. Light spot 58 is shown above or to the left of track center 12 by a distance SR and is shown ahead of light spot 56 by a distance ST. Light spots 54, 56, 58 must be sufficiently spatially separated from one another so as to prevent mutual interference. Nevertheless, light spots 54, 56, 58 must also be sufficiently close to each other in the radial direction so as to provide coverage over the possible variations in the positions of marks 14, 16, 18, 20, 22, 24, 26. In practice, it has been found that light spots 54, 56, 58 should be separated from each other by about one spot diameter in the radial direction (SR) and at least several spot diameters in the tangential direction (ST). The number and orientation of light spots 54, 56, 58 shown in FIG. 3 is one preferred embodiment, however, those of ordinary skill in the art will recognize that other numbers and orientations of light spots are possible and these should be considered within the scope of the disclosed invention.

Turning now to FIG. 4, a block diagram of a radial offset decoder for the playback apparatus for the multidimensional optical recording medium according to the present invention is shown. Recall from the discussion of FIG. 2 above that processor 42 transforms the PD electrical signals into PDP electrical signals that can be described by the function PDP(i). Based on this, the radial offsets of the marks can be determined from PDP(i) by interpolation. For example, through linear interpolation, the radial offset of the marks (RM) can be determined as

$$RM = m(SR) \pm 0.5(SR)[1 + (PD(m \pm 1)-PD(m))/(PDM-PDSR)] \quad (3)$$

where PDM is the maximum possible signal at PD(i), which occurs when the location of the mark coincides with the light spot associated with PD(i), PD(m) is the maximum signal measured by all of the elements of the array, $PD(m) \geq PD(i)$, and the + or - sign is chosen according to whether PD(m+1) or PD(m-1) gives the next highest signal. One possible implementation of equation 3 is shown in FIG. 4.

FIG. 4 also shows tangential decoder 62 which derives its signal from the sum 60 of PD(m) and PD(m ±1). This sum signal is the equivalent of a data signal in the conventional one-dimensional encoding scheme outlined above. As a result, when equipped with tangential decoder 62, playback apparatus 28 of FIG. 2 can playback either conventional one-dimensional media or multidimensional media of the present invention.

Turning now to FIG. 5, a block diagram of a radial width and/or offset decoder for the playback apparatus for the multidimensional optical recording medium according to the present invention is shown. Recall from the discussion of FIG. 2 above that processor 42 transforms the PD electrical signals into PDP electrical signals that can be described by the function PDP(i). Based on this, the radial widths and/or offsets of the marks can be determined from PDP(i) through maximum likelihood detection by comparison to a set of known values. For example, the radial widths and/or offsets of the marks can be determined by comparing the measured values of PDP(i) to the know values of PDP(i,j) that are expected from a mark representing the symbol S(j). Maximum likelihood detection may consist of determining the symbol S(J) that gives the minimum value for the metric

$$E(j) = \sum_{i} [PDP(i) - PDP(i,j)]^2 \qquad (4)$$

where S(J) would be considered the detected symbol. Maximum likelihood detector 70 is shown connected to the output of processor 42 in FIG. 5.

Turning now to FIG. 6, a block diagram of recording apparatus 78 for the multidimensional optical recording medium according to the present invention is shown. A single light beam emitted by laser diode 80 is directed as incident light to polarization beam splitter (PBS) and quarter wave plate (QWP) assembly 82. The light beam transmitted through PBS and QWP assembly 82 is focussed onto optical disc 84 through objective lens 86. The focussed light beam forms a recording light spot on the surface of optical disc 84.

Light reflected by optical disc 84 is directed to PBS and QWP assembly 82 through objective lens 86. The reflected light is separated from the incident light by PBS and QWP assembly 82 and is sent to photodetector array (PD) 88. Optical disc 84 contains preformatted track following and clock synchronization servo marks. The deviations in the position of the recording light spot from these marks can be determined by signals from PD 88. Further, PD 88 verifies that the light spot is maintained on track.

Data to be encoded onto optical disc 84 is fed into encoder 90 which transforms the data into encoded electrical signals that determine the tangential position, tangential length, radial width, radial offset, and mark characteristic such as depth or reflectivity of the mark. Spindle motor 92 rotates optical disc 84 so that the recording light spot scans the media in the tangential direction along the track. Deflector electronics 94 drives deflector 96 to govern radial width and radial offset of the mark. Modulator 98 switches laser diode 80 on and off to govern mark characteristics such as depth or reflectivity of the mark.

Also shown in FIG. 6 is timing and servo control 100 which regulates the rotation speed and direction of spindle motor 92, positions objective lens 86 to be in focus and on track on optical disc 84, and provides timing information for data encoding.

Those of ordinary skill in the art will recognize that the various components of recording apparatus 78 are similar to components that are generally available. Accordingly, the present invention provides a high density optical disc recording medium recording apparatus without significantly departing from existing technology. Further, the present invention provides a high density optical disc recording medium recording apparatus without wasting disc surface area through the use of guide tracks. Further still, the present invention provides a high density optical disc recording medium recording apparatus which can be manufactured with the existing manufacturing base without requiring a major investment in all aspects of the optical disc industry.

While illustrative embodiments and applications of this invention have been shown and described, it would be apparent to those skilled in the art that many more modifications than have been mentioned above are possible without departing from the inventive concepts set forth herein. The invention, therefore, is not to be limited except in the spirit of the appended claims.

What is claimed is:

1. A multidimensional optical recording medium comprising:

a plurality of tracks having a tangential length, a radial width, and a track center; and

a plurality of marks having a tangential position, a tangential length, a radial width, a radial offset, and a mark characteristic, wherein the plurality of marks are formed in each of the plurality of tracks and the plurality of marks represent encoded data that is encoded into the plurality of marks by modulating at least one of the radial width of the mark and the radial offset of the mark.

2. The medium according to claim 1 wherein the encoded data that is represented in the plurality of marks is additionally encoded into the plurality of marks by modulating at least one of the tangential position of the mark, tangential length of the mark, and the mark characteristic.

3. A method for encoding data into a multidimensional optical recording medium comprising a plurality of tracks having a tangential length, a radial width, and a track center, and a plurality of marks having a tangential position, a tangential length, a radial width, a radial offset, and a mark characteristic, wherein the plurality of marks are formed in each of the plurality of tracks, the method comprising the step of:

modulating at least one of the radial width of the mark and the radial offset of the mark.

4. The method according to claim 3 further comprising the step of modulating at least one of the tangential position of the mark, the tangential length of the mark, and the mark characteristic.

5. A method for encoding data into a multidimensional optical recording medium comprising the steps of:

providing a multidimensional optical recording medium comprising a plurality of tracks having a tangential length, a radial width, and a track center, and a plurality of marks having a tangential position, a tangential length, a radial width, a radial offset, and a mark characteristic, wherein the plurality of marks are formed in each of the plurality of tracks; and

modulating at least one of the radial width of the mark and the radial offset of the mark.

6. The method according to claim 5 further comprising the step of modulating at least one of the tangential position of the mark, the tangential length of the mark, and the mark characteristic.

7. A method for decoding data from a multidimensional optical recording medium comprising a plurality of tracks having a tangential length, a radial width, and a track center, and a plurality of marks having a tangential position, a tangential length, a radial width, a radial offset, and a mark characteristic, wherein the plurality of marks are formed in each of the plurality of tracks and the plurality of marks represent encoded data that is encoded into the plurality of marks by modulating at least one of the radial width of the mark and the radial offset of the mark, the method comprising the step of:

demodulating at least one of the radial width of the mark and the radial offset of the mark.

8. The method according to claim 7 wherein the encoded data that is represented in the plurality of marks is additionally encoded into the plurality of marks by modulating at least one of the tangential position of the mark, the tangential length of the mark, and the mark characteristic, the method further comprising the step of demodulating at least one of the tangential position of the mark, the tangential length of the mark, and the mark characteristic.

9. A method for decoding data from a multidimensional optical recording medium comprising the steps of:

providing a multidimensional optical recording medium comprising a plurality of tracks having a tangential length, a radial width, and a track center, and a plurality of marks having a tangential position, a tangential length, a radial width, a radial offset, and a mark characteristic, wherein the plurality of marks are formed in each of the plurality of tracks and the plurality of marks represent encoded data that is encoded into the plurality of marks by modulating at least one of the radial width of the mark and the radial offset of the mark; and

demodulating at least one of the radial width of the mark and the radial offset of the mark.

10. The method according to claim 9 wherein the encoded data that is represented in the plurality of marks is additionally encoded into the plurality of marks by modulating at least one of the tangential position of the mark, the tangential length of the mark, and the mark characteristic, the method further comprising the step of demodulating at least one of the tangential position of the mark, the tangential length of the mark, and the mark characteristic.

11. An apparatus for encoding data into a multidimensional optical recording medium comprising a plurality of tracks having a tangential length, a radial width, and a track center, and a plurality of marks having a tangential position, a tangential length, a radial width,

a radial offset, and a mark characteristic, wherein the plurality of marks are formed in each of the plurality of tracks, the apparatus comprising:

means for modulating at least one of the radial width of the mark and the radial offset of the mark.

12. The apparatus according to claim 11 further comprising means for modulating at least one of the tangential position of the mark, the tangential length of the mark, and the mark characteristic.

13. An apparatus for decoding data from a multidimensional optical recording medium comprising a plurality of tracks having a tangential length, a radial width, and a track center, and a plurality of marks having a tangential position, a tangential length, a radial width, a radial offset, and a mark characteristic, wherein the plurality of marks are formed in each of the plurality of tracks and the plurality of marks represent encoded data that is encoded into the plurality of marks by modulating at least one of the radial width of the mark and the radial offset of the mark, the apparatus comprising:

means for demodulating at least one of the radial width of the mark and the radial offset of the mark.

14. The apparatus according to claim 13 wherein the encoded data that is represented in the plurality of marks is additionally encoded into the plurality of marks by modulating at least one of the tangential position of the mark, the tangential length of the mark, and the mark characteristic, the apparatus further comprising means for demodulating at least one of the tangential position of the mark, the tangential length of the mark, and the mark characteristic.

15. An apparatus for playback of data from a multidimensional optical disc comprising a plurality of tracks having a tangential length, a radial width, and a track center, and a plurality of marks having a tangential position, a tangential length, a radial width, a radial offset, and a mark characteristic, wherein the plurality of marks are formed in each of the plurality of tracks and the plurality of marks represent encoded data that is encoded into the plurality of marks by modulating at least one of the radial width of the mark, the radial offset of the mark, the tangential position of the mark, the tangential length of the mark, and the mark characteristic, the apparatus comprising:

a source of a plurality of light beams to serve as incident light to the optical disc;

means for beam splitting for directing the incident light to the optical disc which reflects at least a portion of the incident light back to the means for beam splitting which separates the reflected light from the incident light;

an objective lens for focussing the incident light on the optical disc;

a photodetector array for detecting the reflected light from the means for beam splitting;

a processor for transforming the electrical signals from the photodetector array;

a spindle motor for rotating the optical disc at a predetermined speed and in a predetermined direction;

a timing and servo control for regulating the rotation speed and direction of the spindle motor, for positioning the objective lens to be in focus and on track on the optical disc; and

a decoder for demodulating at least one of the radial width of the mark and the radial offset of the mark.

16. The apparatus according to claim 15 wherein the source of a plurality of light beams further comprises a laser diode and a diffraction grating.

17. The apparatus according to claim 15 wherein the processor further comprises a delay circuit, a cross talk canceler, and an equalization filter.

18. The apparatus according to claim 15 wherein the decoder further comprises a radial decoder and a tangential decoder.

19. The apparatus according to claim 15 wherein the decoder comprises a maximum likelihood detector.

20. An apparatus for recording data into a multidimensional optical disc comprising a plurality of tracks having a tangential length, a radial width, and a track center, and a plurality of marks having a tangential position, a tangential length, a radial width, a radial offset, and a mark characteristic, wherein the plurality of marks are formed in each of the plurality of tracks, the apparatus comprising:

a laser diode for generating a light beam to serve as incident light to the optical disc;

means for beam splitting for directing the incident light to the optical disc which reflects at least a portion of the incident light back to the means for beam splitting which separates the reflected light from the incident light;

an objective lens for focusing the incident light on the optical disc to form a recording light spot;

a photodetector array for detecting the reflected light from the assembly to verify that the recording light spot is maintained on track;

a spindle motor for rotating the optical disc at a predetermined speed and in a predetermined direction so that the recording light spot scans the optical disc in the tangential direction;

a deflector control for driving a deflector to govern the radial width of the mark and radial offset of the mark;

a modulator for switching the laser diode on and off to govern the tangential position of the mark, the tangential length of the mark, and the mark characteristics of the mark;

a timing and servo control for regulating the rotation speed and direction of the spindle motor, for positioning the objective lens to be in focus and on track on the optical disc; and

an encoder for modulating at least one of the radial width of the mark and the radial offset of the mark.

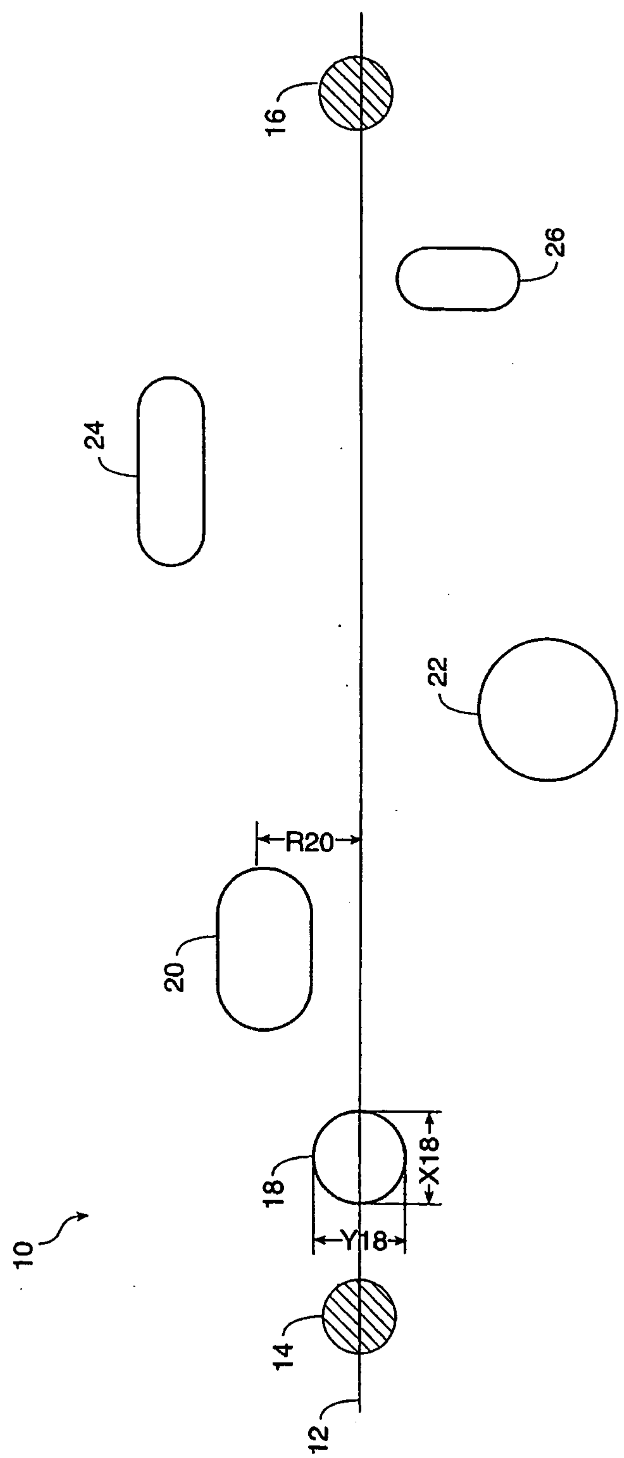

FIG. 1

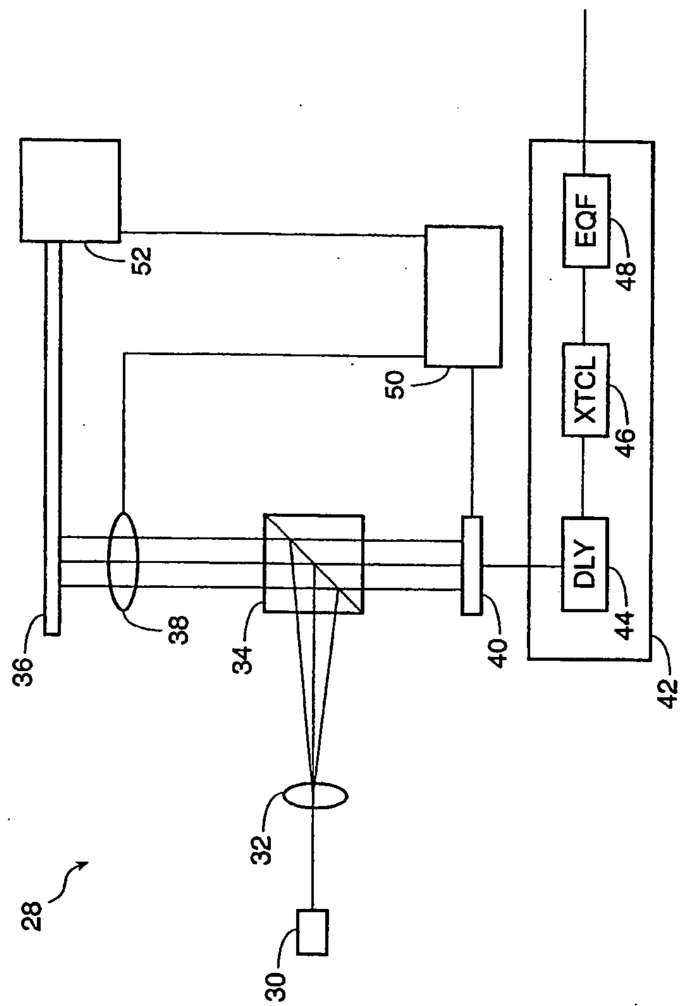

FIG. 2

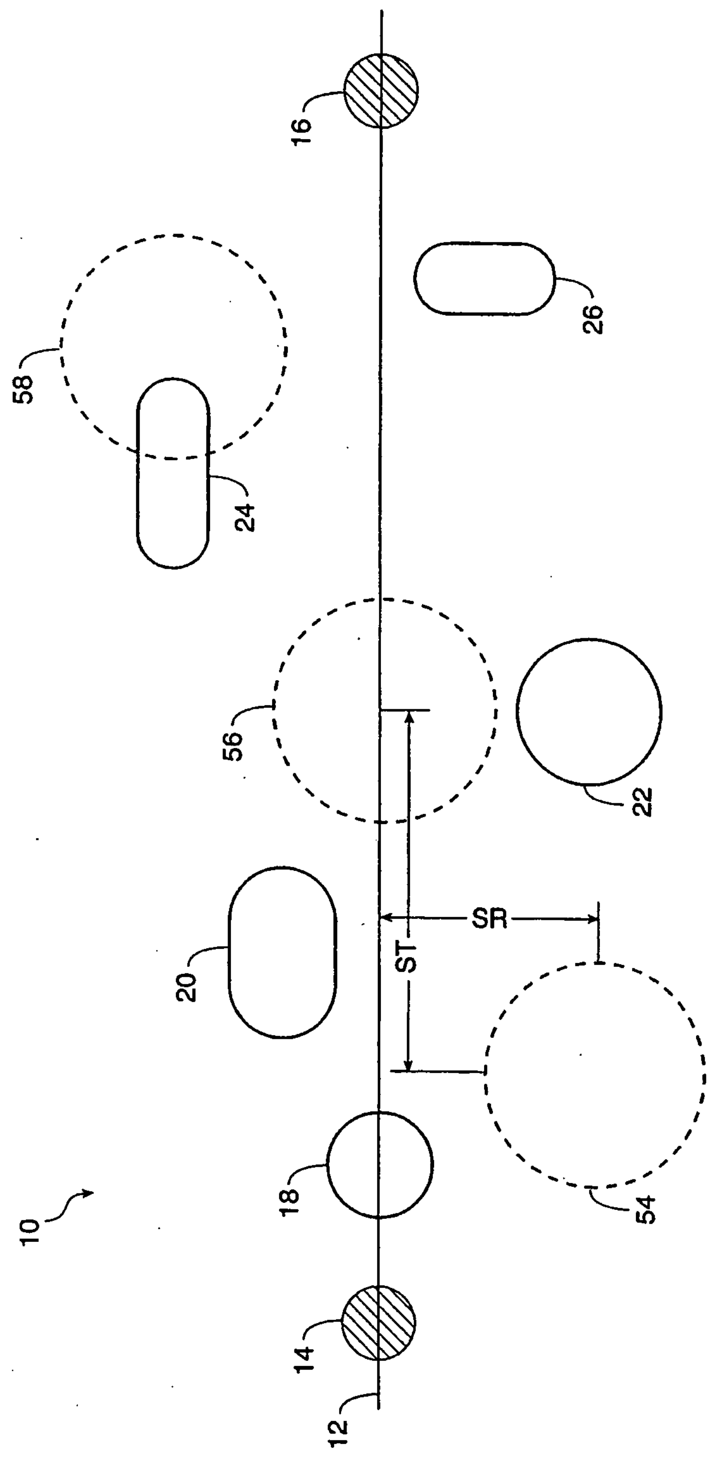

FIG. 3

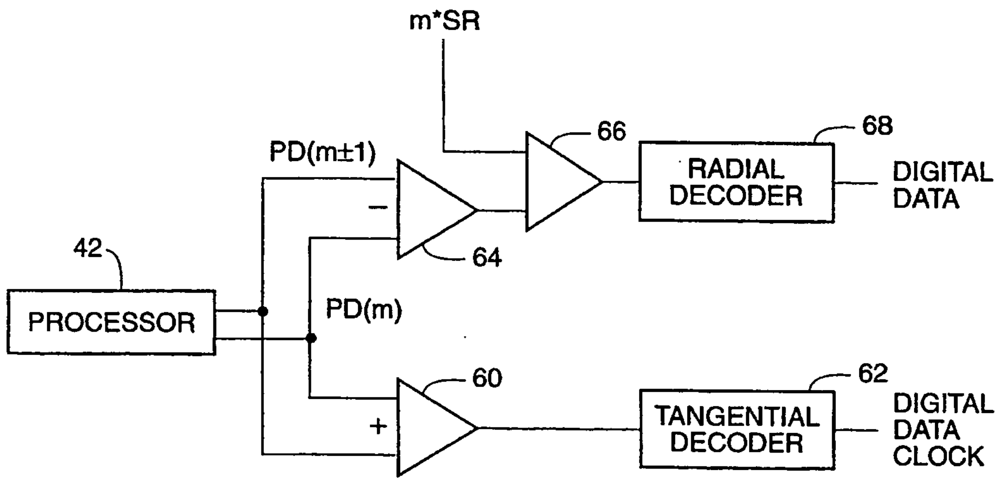
m*SR
66
68
PD(m±1)
RADIAL
DECODER
DIGITAL
DATA
42
64
PROCESSOR
PD(m)
60
62
TANGENTIAL
DECODER
DIGITAL
DATA
CLOCK

FIG. 4

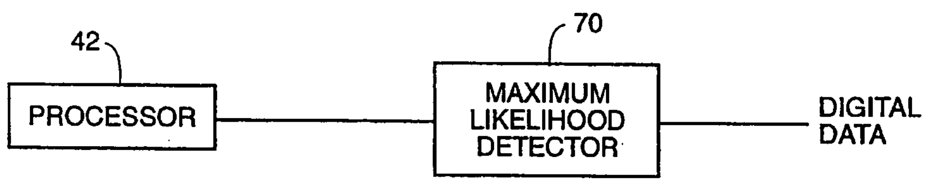
42
70
PROCESSOR
MAXIMUM
LIKELIHOOD
DETECTOR
DIGITAL
DATA

FIG. 5

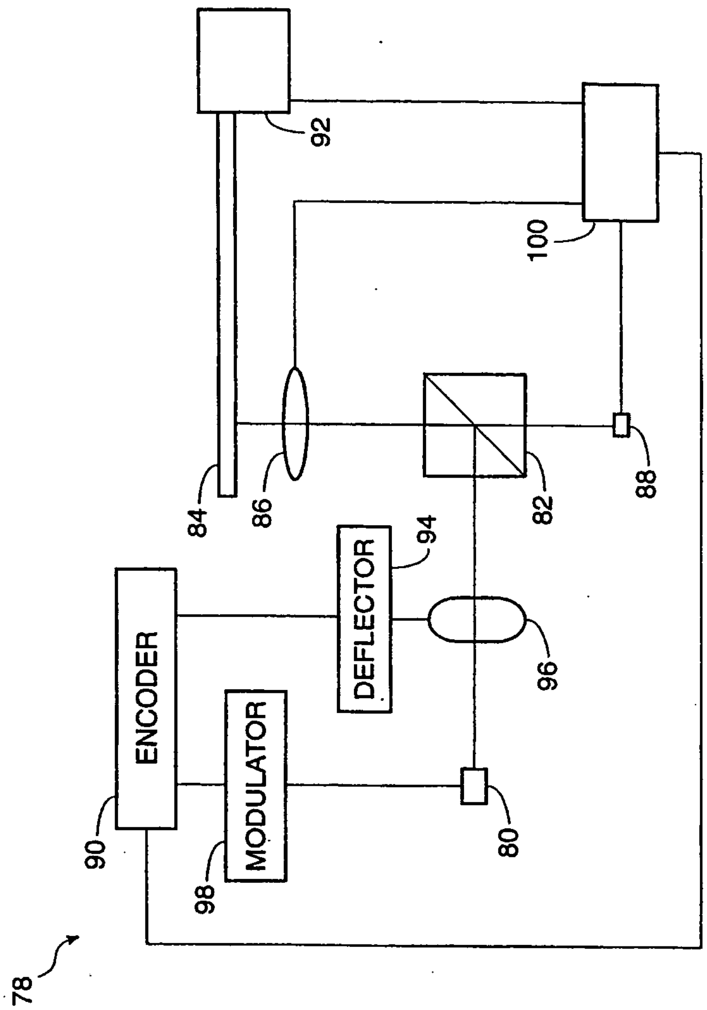
ENCODER
MODULATOR
DEFLECTOR
78
80
82
84
86
88
90
92
94
96
98
100

FIG. 6